Application for
UNITED STATES LETTERS PATENT

Of

MARIKO YAMADA

MASASHI YANO

AKIRA DATE

AND

TAKUMI OISHI

For

PACKET COMMUNICATION SYSTEM, COMMUNICATION NETWORK, AND
METHOD FOR SELECTING IP ADDRESS IN MOBILE NODE

TITLE OF THE INVENTION

PACKET COMMUNICATION SYSTEM, COMMUNICATION NETWORK, AND METHOD FOR SELECTING IP ADDRESS IN MOBILE NODE

5   BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to a communication system that uses mobile IP, and especially relates to a method for selecting a communication IP address in a mobile node that

10. moved from its home network to a foreign network.

Description of the Related Art

In the Internet, it is common that when a mobile node moved among networks, the mobile node newly acquires an IP address in a network to which it moved (hereinafter

15   sometimes referred to as "visited") and performs communication with it.

On the other hand, IETF is now standardizing a method whereby a mobile node performs communication in a visited network to which it moved (hereinafter a network being

20   referred to as a "foreign network") without altering the IP address of the mobile node by using the IP address that has been assigned to the mobile node (hereinafter referred.to as a "home address") in a network to which the mobile node is usually attached (hereinafter referred to as a "home

25   network").

        In "Mobility Support in IPv6" (David B. Johnson,
draft-ietf-mobileip-ipv6-20.txt, Jan/2003) that is being
examined in IETF (hereinafter referred to as a "mobile IP"),
a terminal that wishes to communicate with a mobile node sets
5   a destination IP address as the mobile node's home address
and sends an IP packet. The IP packet that was routed to
the mobile node's home address is captured by the mobile
node's home agent and is transferred after being
encapsulated to a foreign network visited by the mobile
10   node.

        In order to encapsulate and forward the IP packet that
was received, the home agent receives a binding update from
the mobile node and manages association between the mobile
node's home address and the IP address that the mobile node
15   acquired in the foreign network (hereinafter referred to as
a "care-of address"). This procedure makes it possible for
the mobile node to receive the IP packet addressed to its
home address in the foreign network. When communication
starts between the mobile node and the terminal, the binding
20   update will be sent to the terminal of a partner of
communication from the mobile node; therefore, it is also
possible for the mobile node and the terminal to communicate
directly between each other henceforth not via the home
agent but by using a routing header that is an extension
25   header of IPv6. Moreover, if a home agent exists on a first

foreign network that is a network visited by the mobile node, after the mobile node has moved to a second foreign network, it is also possible to forward a packet addressed to the mobile node to the mobile node residing in the second foreign network by sending the binding update to the first foreign network's home agent.

[Non-patent literature 1]

David D. Johnson et al. "Mobility Support in IPv6 draft-ietf-mobileip-ipv6-20.txt," obtained online from IETF on January 20, 2003, also available from the Internet <http://www.ietf.org/internet-drafts/draft-ietf-mobileip-ipv6-20.txt> [searched on February 5, 2003]

With the technology described above, the mobile node will be able to communicate with the terminal using its home address even when it has moved among networks. Moreover, the mobile node in a foreign network can select either its home address or the care-of address that was acquired in the foreign network as a communication address.

For example, if the communication address is set to the mobile node's home address, the mobile node can receive a packet surely even when it moves from one network to another. However, in this case, since the IP packets are encapsulated and forwarded by the home agent to reach the mobile node, an overhead of communication is created. After the start of the communication, it is possible to eliminate

the overhead of communication by sending the binding update to a partner of the communication and hence setting up route optimization. However, it is impossible to set up the route optimization from the time of start of the communication.

5   On the other hand, in the case where the communication address is set to a care-of address, since the mobile node can directly communicate with the partner of communication, the overhead of communication can be eliminated. However, when the mobile node has left the first foreign network and

10   moved to the second foreign network, IP packets addressed to the mobile node that have reached the first foreign network may not be forwarded to the second foreign network, and so there is the possibility that the mobile node may not be able to maintain a session with the partner of

15   communication.

SUMMARY OF THE INVENTION

It is the object of this invention to provide a communication system that uses a mobile IP, a communication

20   network, and a method for selecting an IP address in a mobile node whereby a route can be optimized as much as possible and a session can be maintained even when the mobile node has moved from a foreign network to which the mobile node is currently attached to another foreign network,

In order to achieve the above-mentioned object, the communication system is configured to have first and second packet communication devices that are arranged in at least first and second foreign networks, respectively, selected

5 from among a plurality of foreign networks existing as networks visited by the mobile node, wherein when the mobile node has moved to the first foreign network, a first care-of address is given to the mobile node, when the mobile node has moved to the second foreign network, a second care-of

10 address is given to the mobile node, respectively, and after the mobile node has moved from the first foreign network to the second foreign network, when a packet addressed to the first care-of address is transmitted, the first packet communication device forwards the packet to the second

15 packet communication device.

According to this invention, it becomes possible for the mobile node to select such a mobile IP address, as the communication address for communication with a terminal, that enables route optimization to be set up as much as

20 possible while a communication session is maintained even when moving from the first foreign network to the second foreign network.

Thereby, the overhead of communication that increases by processing of encapsulation can be reduced. Moreover,

25 while the mobile node is staying at a foreign network where

a temporarily available home agent exists, the mobile node
can use that home agent as a temporary home agent, and the
mobile node can receive packets that are not encapsulated.
Therefore, the communication system can suppress increase

5   of the load that accompanies processing encapsulated
packets. Furthermore, even when the mobile node moves to
another foreign network, it becomes possible for the mobile
node to maintain a session with the partner of
communication.

10   In addition, when the mobile node moves among a
plurality of foreign networks, a hand-over time can be kept
constant by changing a home agent that is used temporarily
and the overhead of communication can be reduced.

15   BRIEF DESCRIPTION OF THE DRAWINGS
        FIG. 1 is an illustration conceptually showing a
network to which this invention is applied;
        FIG. 2 is a block diagram showing an internal
composition of the mobile node used in this invention;

20   FIG. 3 is a flowchart showing a processing flow from
foreign network movement detection to address selection
that is performed in the mobile node;
        FIG. 4 is a flowchart showing a processing flow of
binding management performed in the mobile node;

FIG. 5 is a conceptual diagram explaining the composition of a home agent list;

FIG. 6 is a conceptual diagram explaining the composition of a binding list;

5   FIG. 7 is a conceptual diagram explaining the composition of an on-communication address table;

FIG. 8 is a sequence diagram explaining a process in which a communication path in a foreign network is optimized;

10   FIG. 9 is a conceptual diagram for explaining a process in which a home agent is changed over;

FIG. .10 is a conceptual diagram explaining the composition of a home-agent change conditions setting table;

15   FIG. 11 is a flowchart showing a processing flow of changing a home agent that is performed in the mobile node; and

FIG. 12 is a view showing an example in which this invention is applied to a network such that a temporary home
20   agent does not exist on a foreign network to which the mobile node is directly connected.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereafter, embodiments according to this invention
25   will be described.

First Embodiment

This invention will be described by giving an example where the mobile node registers the communication IP address dynamically at an IP address management server.

5   FIG. 1 is a view showing an example of the composition of a mobile IP communication system in which this invention is put into practice. The mobile IP communication system is composed of: a home agent (102), a terminal A (109) that communicates with a mobile node (103), an IP address

10   management server that enables the terminal to resolve an address of the mobile node (103), a home network (101) to which the mobile node (103) is attached and that the home agent (102) of the mobile node (103) belongs to, a foreign network 1 (104) and a foreign network 2 (106) that are

15   networks visited by the mobile node (103), etc.

The home network (101), the foreign network 1 (104), the foreign network 2 (106), and a network that the terminal A (109) belongs to are connected with one another via the Internet (110). The terminal A (109) is assumed as a

20   correspondent node of a mobile IP.

First, the mobile node (103) registers its IP address at an IP address management server (108) in the home network (101). The terminal A (109) inquiries the IP address of the mobile node (103) to the IP address management server (108)

25   and resolves the IP address of the mobile node (103). The

communication terminal A (109) starts to communicate with the mobile node (103) using the IP address acquired from the IP address management server (108) as the destination IP address. As will be described below, the IP address

5 management server (108) is capable of dynamically changing an association between an identifier of the mobile node (103) and an IP address based on notification from the mobile node (103).

FIG. 2 is a view showing the internal composition of

10 the mobile node (103). The mobile node (103) has an OS (403) on its hardware (402). The OS (403) is assumed to have a packet transmission/reception processing part for transmitting/receiving IP packets (407) and a tunneling and routing header processing part for performing decapsulation

15 of IP packets and the like (406) as well as basic OS functions (405).

The mobile node (103) has also a mobile IP processing part (404) in addition to the hardware (402) and the OS (403).

20 The mobile IP processing part (404) comprises: a movement detection processing part (408), a mobile IP message processing part (409), a binding management part (410), a home agent list (411), a binding list (412), and a mobile node information table (413).

The mobile IP processing part (404) further comprises: an address selection processing part (501), a communication address management processing part (502), an on-communication address management table (503), a network status table (504), and a home-agent change processing part (505).

The movement detection processing part (408) analyzes a router advertisement that is notified in a network to which the mobile node (103) is currently attached and judges whether the mobile node (103) has moved from a network. The movement detection processing part (408) further judges whether the first foreign network to which the mobile node (103) is currently connected can forward IP packets to a second foreign network in which the mobile node (103) is going to reside next. That is, when a home agent flag is on in a prefix information option of a router advertisement received from the second foreign network, a packet communication device capable of forwarding IP packets addressed to a care-of address, namely a home agent exists, and hence the movement detection processing part (408) judges that forwarding is possible; when the home agent flag is not on, it judges that the forwarding is impossible. The movement detection processing part (408) makes the network state table (504) reflect the judgment result.

When the movement detection processing part (408)
receives router advertisements sent from a plurality of
routers or home agents, it specifies the routers or home
agents that sent out the router advertisement based on link
5   local addresses of source addresses of the respective router
advertisements. If a home agent that set a home agent flag
on and sent a router advertisement previously sends a router
advertisement without setting the flag on, the movement
detection processing part (408) judges that a network
10   situation has changed and the home agent has become
incapable of the forwarding. Note that in this
specification a packet communication device capable of
forwarding IP packets addressed to a care-of address is
called a home agent, whereas a packet communication device
15   incapable of the forwarding is called a router.

The mobile IP message processing part (409) processes
mobile IP messages, such as binding updates and binding
acknowledgements.

The binding management part (410) manages information
20   as to which is a terminal under the binding with the mobile
node (103). The home agent list (411) is a list of home
agents each capable of providing a home agent function to
the mobile node (103). As is illustrated in FIG. 5, the home
agent list (411) contains at least a home agent's global IP
25   address (4111), a home agent's link local address (4112),

a home agent's priority (4113), and a home agent's lifetime
(4115). The contents of the home agent list (411) are
updated by analyzing the router advertisement in the
movement detection processing part (408). For example, in
5 the case where, as was described above, a home agent that
notified a router advertisement with a home agent flag being
on up to now notifies a router advertisement wit the home
agent flag not being on, it is judged that a network
situation has changed and the home agent has become
10 incapable of the forwarding, and thus the contents of the
home agent list (411) are updated.

The binding list (412) is a table for managing
destinations to which the mobile node (103) sent the binding
updates. As is illustrated in FIG. 6, the binding list (412)
15 contains: a destination of the binding update (4121); a
care-of address acquired in the current foreign network
(4122); a home address (4123) of the mobile node (103); and
a lifetime of the binding list (4124).

The binding list (412) is updated by the mobile IP
20 message processing part (409) and is managed by the binding
management part (410). For example, the binding management
part (410) judges whether it expired the life time recorded
in the binding list (412) (timeout), and if the time is
judged to be up, the binding management part (410) further

judges whether the binding needs to be updated (continued) based on information of the on-communication address table.

The mobile node information table (413) holds setting information of the mobile node (103), such as the home

5   address of the mobile node (103) and the home agent address.

The address selection processing part (501) selects an IP address to be used for communication by knowing the state of a network to which the mobile node (103) is connected.

10   The communication address management processing part (502) manages the IP address that an application having been started in the mobile node (103) is using for communication.

The on-communication address management table (503) is a list of IP addresses that applications having been

15   started in the mobile node (103) are using for communication. The on-communication address management part (503) manages kinds of applications (5031) having been started by the mobile node (103) and the IP addresses that the applications (5031) use for IP communication (5032) in

20   cooperation with the OS (403), as is illustrated in FIG. 7. The on-communication address management table (503) also contains an address attribute (5033) that indicates whether the IP address being used for communication is the home address of the mobile node (103) or a care-of address that

the mobile node (103) acquired in a foreign network to which the mobile node (103) was previously attached.

FIG. 3 is a flowchart that shows a processing flow from movement detection to address selection processing that is executed in the mobile node (103).

The mobile node (103) receives the router advertisement sent by either a router or a home agent in a subnet to which the mobile node (103) is currently attached (step 601).

The mobile node (103) acquires a prefix of the foreign network from a prefix information option contained in the router advertisement and compares it with a prefix of the home network of the mobile node (103). The mobile node (103) detects whether the mobile node (103) has moved between subnets from a result of this comparison result (step 602).

The mobile node (103) that detected the movement judges whether it is necessary to send the binding update to the foreign network to which the mobile node (103) was previously attached (step 603). The judgment on the necessity of sending the binding update is performed by the use of the address attribute (5033) of the on-communication address management table (503). If the address attribute (5033) is the care-of address, the mobile node (103) judges that there is a necessity of sending it.

If it is judged that it is necessary to send the binding update, the mobile node (103) specifies a network to which the binding update must be sent from the use IP address (5032) of the on-communication address management

5   table. The mobile node (103) further specifies a home agent to which the binding update is sent based on a home agent address (HA address) (411) and a priority (4113) in the home agent list (411), and sends the binding update to the home agent of a foreign network in which the mobile node (103)

10   previously resided (step 604). If it is not necessary to send the binding update, the mobile node (103) does not send it.

The mobile node (103) sends the binding update to the home agent (102) of the mobile node (103) (step 605).

15   The mobile node (103) judges whether a home agent (105) on the foreign network 1 (104) to which the mobile node is currently connected has a function of forwarding a packet that was delivered to the current care-of address to the foreign network 2 (107) based on information in the network

20   status table (504) (step 606).

If the judgment is that the forwarding is impossible, the mobile node (103) selects the home address as the communication address (step 607); if the judgment is that the forwarding is possible, the mobile node (103) selects

a current care-of address as the communication address (step 608).

FIG. 4 is a flowchart showing a processing flow of the binding management performed in the mobile node (103).

5   When lifetime of an IP address (4124) registered in the binding list (412) runs out (step 701), the mobile node (103) searches the on-communication address management table (503) to detect a use IP address whose address attribute is a care-of address (step 702).

10   The mobile node (103) judges whether it is necessary to send the binding update to a destination whose binding time runs out (4121) (step 703). If a network part of a destination (4121) whose binding time runs out agrees with a network of the IP address detected at step 702, an

15   application is performing communication using a care-of address that designates a destination whose binding time runs out as the home agent. In this case, the mobile node (103) sends the binding update to an address of the binding list (step 704). If the agreement is not obtained, the

20   mobile node (103) does not send the binding update.

.The mobile node (103) updates the binding list (step 705). In the case where the binding update was not sent, the corresponding binding list is deleted; in the case where the binding update is sent, the lifetime of the

25   corresponding binding list is updated in conformity to the

lifetime of the sent binding update. The above processing flow will be explained referring to FIG. 1 again. Here it is assumed that the mobile node (103) has already moved from the home network (104) to the foreign network 1 and is moving

5 from there to the foreign network 2.

The mobile node (103) selects the care-of address as the communication address in the foreign network 1 (104). Moreover, the mobile node (103) registers the care-of address at the IP address management server (108), and this

10 procedure makes it possible for the terminal A (109) that communicates with the mobile address (103) to communicate with the mobile node (103) residing in the foreign network 1 (104) using a communication path that has been optimized from the start of the communication (Path 111).

15 Moreover, when the mobile node (103) has moved to the foreign network 2 (106), this mobile node (103) sends the binding update to the home agent (105) on the foreign network 1 (104). Thereby, the home agent (105) belonging to the foreign network 1 (104) is enabled to capture IP packets sent

20 to the mobile node's care-of address (Path 112) and forward it to the mobile node in the foreign network 2 (106) (Path 113); therefore a communication session can be maintained. FIG. 8 shows a communication sequence in which the mobile node (103) communicates with the terminal A (109) by the

25 method for selecting an IP address according to this

invention. Here, the above-mentioned communication
sequence will be explained referring to FIG. 1 and FIG. 8.
The mobile node (103) receives the router advertisement in
the foreign network 1 (104), detects that it has moved

5   between the networks (Event 1101), and sends the binding
update to the home agent (102) of the mobile node (103)
(Event 1102).

The mobile node (103) judges from the received router
advertisement that the home agent (105) exists on the

10   foreign network 1 (104), and packets addressed to the
care-of address can be forwarded to another network. Then
the mobile node (103) selects the care-of address as the
communication address. The mobile node (103) registers the
selected communication address at the IP address management

15   server (Event 1103). The terminal A (109) that is going to
start communication with the mobile node (103) inquires the
mobile node's address at the IP address management server
(108) (Event 1104) and resolves the address (Event 1105).
The terminal A (109) sends IP packets to the care-of address

20   of the mobile node acquired from the IP address management
server (Event 111).

Here, the mobile node (103) moves to the foreign.
network 2 (106) from the foreign network 1 (104). The mobile
node (103) receives the router advertisement in the visited

foreign network 2 (106) (Event 1106) and detects the movement.

The mobile node (103) sends the binding update to the home agent (102) existing on the home network (101) of the mobile node (103) and the home agent (105) on the foreign network 1 (104) (Events 1107, 1108), and registers the current care-of address at the home agents (102, 105).

The IP packet sent to the care-of address of the foreign network 1 (104) from the communication terminal A (109) is captured (Event 112) and encapsulated by the home agent (105) on the foreign network 1 (104), and is forwarded to the mobile node (103) existing on the foreign network 2 (106) (Event 113).

Second Embodiment

This invention will be described by taking an example where the mobile node (103) moves among a plurality of foreign networks one by one. FIG. 9 illustrates how the mobile node (103) is moving among the plurality of networks. When the mobile node (103) moved from a foreign network 1 in which exists a home agent (105) that the mobile node is using temporarily to the plurality of networks, and reached a foreign networks N (1201), namely an N-th foreign network (N: an integer more than 2, as counted from the foreign network 1) in which the mobile node (103) resides, in order to eliminate the overhead of communication caused by packets

passing through the temporary home agent (105) (Path 1203),
it is also possible for the mobile node (103) to perform
communication by changing the temporary home agent to a
neighboring home agent (1202) (Path 1204). Hereafter, this
example will be explained.

Home agent change is done by the mobile node (103)
sending the binding update message (Path 1205). A user of
the mobile node can set up conditions for changing a
temporary home agent as will be described below.

FIG. 10 shows an example of the condition that the user
of the mobile node sets up in advance. For home-agent change
judgment conditions (1301), conditions for performing
home-agent change judgment processing (1302) and values of
the number of hops made with temporary home agents (1303),
delay (1304), etc. are specified as conditions when the
change is performed. Note that defaults values of these
conditions may have been set in advance and the user may be
allowed to change them according to the user's preference.

FIG. 11 shows a processing flow of changing a home
agent performed in the mobile node (103). The mobile node
(103) judges whether a temporary communication path between
the home agent (105) and the mobile node (103) that is
currently being used satisfies the conditions under which
the home-agent change is performed based on the change
judgment conditions that have been set in advance (1301)

(step 1401). If the conditions are not satisfied, the home-agent change processing is not performed.

If the conditions are satisfied, the mobile node (103) judges from the router advertisement whether a temporarily available home agent exists on the foreign network to which the mobile node (103) is currently attached (step 1402). If the temporary home agent can be used, a communication path with the terminal A is changed to the temporary home agent (1202) existing on the foreign network to which the mobile node (103) is currently attached (step 1403).

If a temporarily available home agent does not exist, the mobile node (103) compares which is prioritized, communication via the temporary home agent (105) that is currently being used or communication via the home agent belonging to the home network (101) of the mobile node (103) (step 1404).

If the communication via the home agent (102) belonging to the home network (101) of the mobile node (103) is judged to be prioritized (step 1405), the communication path is changed to a path via the home agent (102) belonging to the home network (101) of the mobile node (103) (step 1406). If the communication via the home agent that is currently being used (102) is judged to be prioritized, home-agent change processing is not performed.

When the home agent that is currently being used is
changed to the temporary home agent (1202) of a foreign
network N (1201) to which the mobile node (103) is currently
attached, a normal binding update message is sent to the
5   terminal A (109). When that home agent is changed to the
home agent (102) belonging to the home network (101) of the
mobile node (103), a binding update message of an alternate
care-of address added with the home address of the mobile
node (103) is sent to the home agent (102) belonging to the
10   home network (101) of the mobile node (103).
Third Embodiment

An example in which this invention is applied in the
case where a home agent does not exist on a foreign network
to which the mobile node (103) is directly connected but a
15   home agent exists on a foreign network that is upstream from
that foreign network.

FIG. 12 shows an example where the temporary home
agent (105) exists upstream from a foreign network 1-1
(1501) to which the mobile node (103) is directly connected.
20   The foreign network 1-1 (1501) and a foreign network 1-2
(1502) have a hierarchical structure of connection such that
the two are connected to a lower layer of the foreign network
1 (104).

The temporary home agent (105) is arranged in the
25   foreign network 1 (104) that is located in the upper level

of the foreign network 1-1 (1501) and the foreign network 1-2 (1502). Thereby, the data addressed to the mobile node (103) reaches the mobile node (103) surely via the foreign network 1 (104) where the temporary home agent (105) exists,

5   and consequently it becomes possible to capture packets sent to the mobile node (103) from the terminal A (109) as in the case of the temporary home agent (105) described in the first embodiment.

     Moreover, for the router advertisement sent out in the

10   foreign network 1-1 (1501), a router advertisement of mobile IP extension, and an address of the temporary home agent (105) existing on the foreign network 1 (104) is set as a prefix information option. Thereby, the mobile node (103) can recognize existence of the temporary home agent (105)

15   arranged upstream from the foreign network 1-1 (1501). In this way, the mobile node (103) can communicate with the terminal A (109) using the same method as was described in the first embodiment.